V. Deep River/ Turkey Creek Water Quality Monitoring Project

To facilitate the development of the Deep River/ Turkey Creek Watershed Management Plan, the scope of work for this project also included an assessment of existing water quality in the watershed to supplement the historical water quality data collected during the initial phases of plan development. With assistance from the consulting team, the Water Quality subcommittee selected nine water quality sampling sites located throughout the watershed. **Figure 5-1** illustrates each of the sampling site locations and **Table 5-1** describes the location of each sampling site.

Figure 5-1. Deep River/ Turkey Creek watershed sampling locations

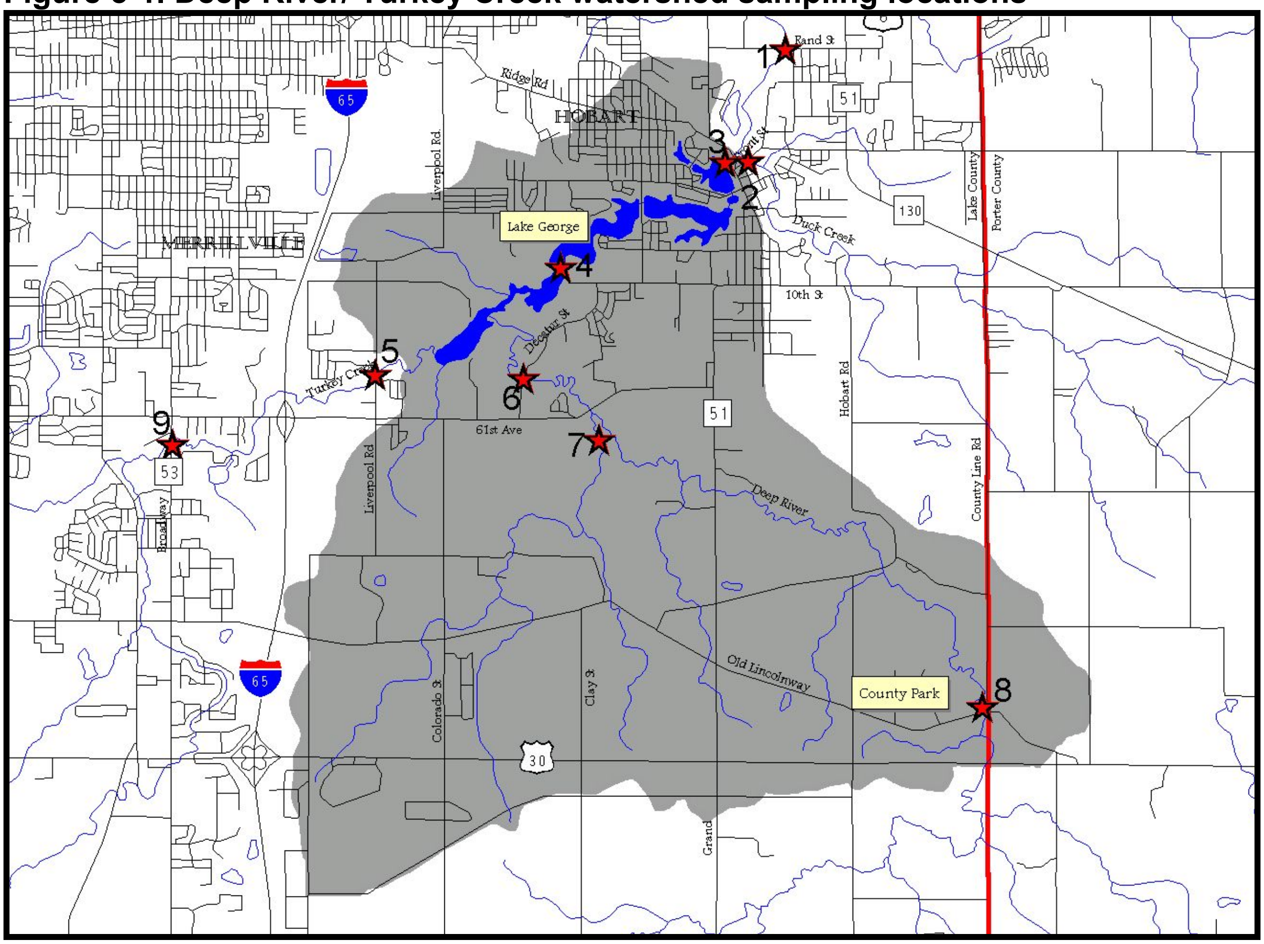


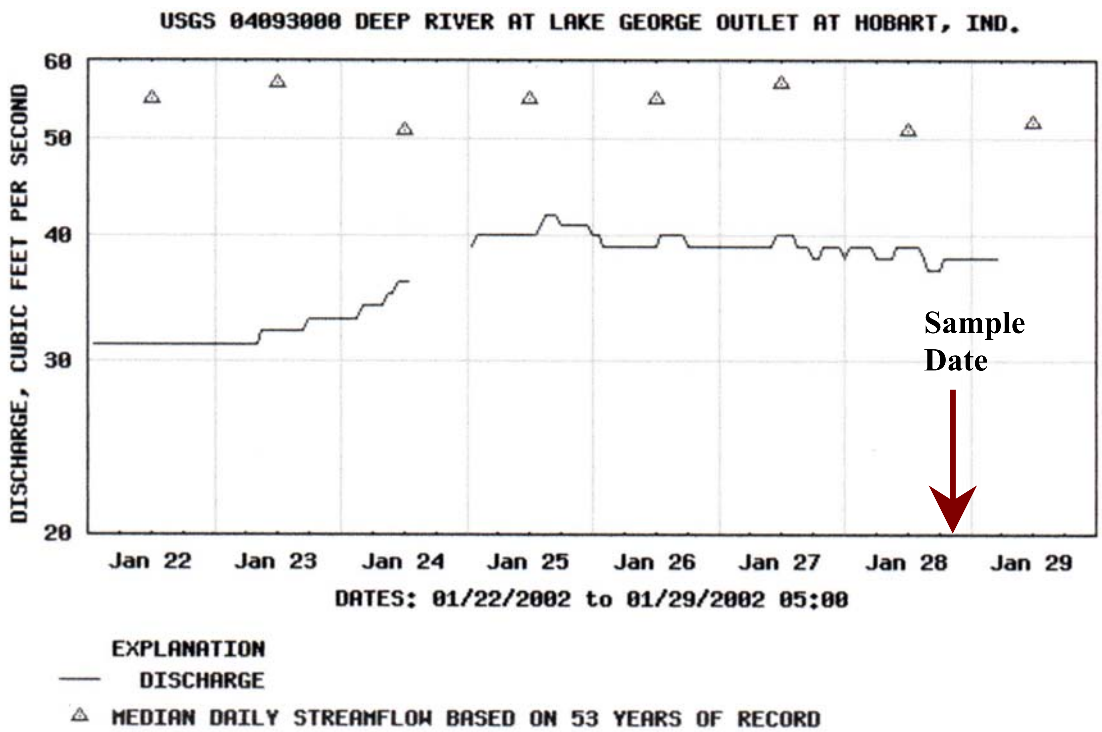
Table 5-1: Sampling Site Locations:

Site 1: Deep River at Rand Street, immediately west of Kelly Street.
Site 2: Duck Creek at Front Street, immediately north of Center Street.
Site 3: Deep River, immediately below the Lake George dam.
Site 4: Lake George, immediately downstream of the wetland at the southwest end of the lake.
Site 5: Turkey Creek at Liverpool Road, immediately north of 16th Street.
Site 6: Deep River at Decatur Street.
Site 7: Unnamed tributary to Deep River.
Site 8: Deep River, immediately northwest of the intersection of County Line Road and the Old Lincoln Highway.
Site 9: Turkey Creek at State Road 53.

J.F. New & Associates (New) collected water quality samples from the sampling sites in the Deep River/ Turkey Creek watershed twice during the study period. The first sampling effort occurred on January 28, 2002 following a period of little precipitation. The hydrograph for the United States Geological Survey (USGS) Lake George gaging station shows discharge at the gage was below the historical median discharge (See **Figure 5-2)**. The historical median is based on 53 years worth of data. This data suggests streams in the watershed were at base flow conditions. Base flow sampling provides an understanding of typical conditions in streams.

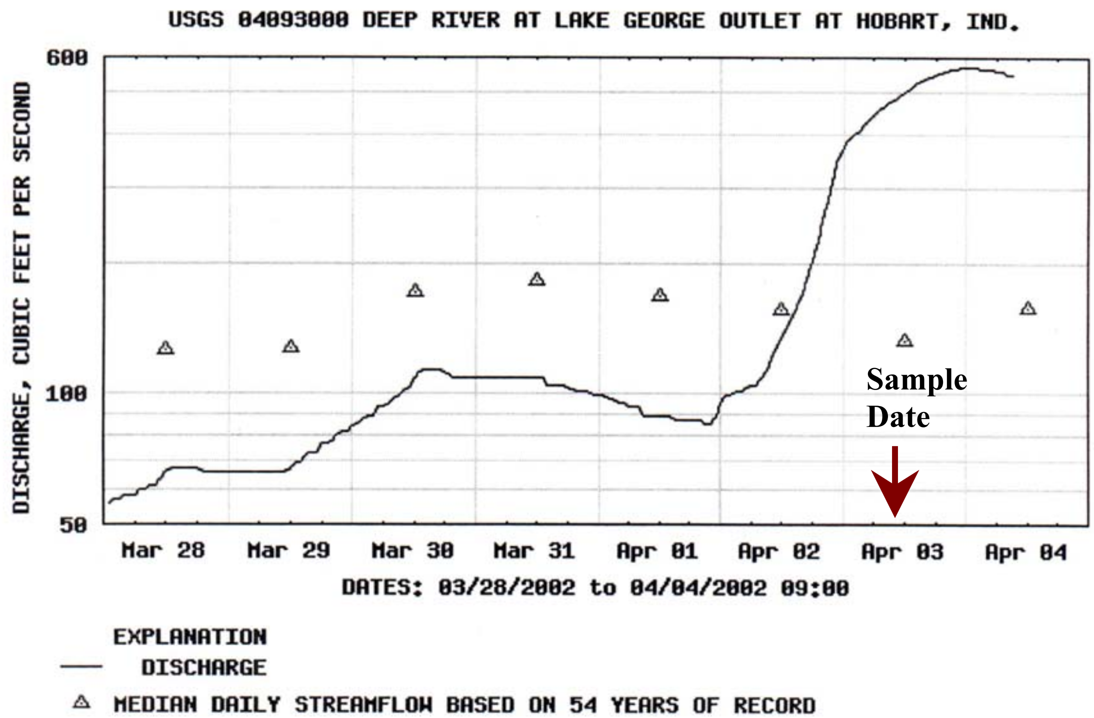
The second sampling effort occurred on April 3, 2002 following two days of rain. Local monitoring stations reported precipitation totals of approximately 0.5 to 1 inch in Lake and Porter Counties (http:/shadow.agry.purdue.edu/sc.index.html/). Discharge at the Lake George gaging station exceeded the historical median discharge peaking at nearly six times the historical value (See **Figure 5-3**). Based on the hydrograph, the April 3rd sampling effort documented storm flow conditions in the watershed streams. Following storm events, the increased overland water flow results in increased erosion of soil and nutrients from the land. In addition, precipitation washes pollutants from hardscape into the watershed. Thus, stream concentrations of nutrients and sediment are typically higher following storm events. In essence, storm sampling presents a "worst case" picture of watershed pollutant loading.

Figure 5-2. Mean daily discharge for the Deep River at Lake George with base flow sampling date noted.



During the collection and analysis of the water quality samples, the sampling crewmembers and the contract laboratory, Severn Trent Laboratories (STL) in Valparaiso, followed the methodologies outlined in the Deep River/ Turkey Creek Quality Assurance Project Plan. The specifics of these methodologies will not be repeated here, but are described in detail in the Quality Assurance Project Plan (QAPP) that was developed for this project. At each sampling site, the sampling crew measured temperature, dissolved oxygen, pH, conductivity and water velocity *in situ*. The sampling crew also measured the cross-sectional area of each stream in order to calculate the stream's discharge.

Figure 5-3. Mean daily discharge for the Deep River at Lake George with storm flow sampling date noted.



The sampling crew collected water at each site in sterile, pre-preserved (where appropriate) sample containers supplied by STL. Based on input from the Water Quality subcommittee and the consulting team, STL analyzed the water quality samples for the following parameters:

- Nitrate-nitrogen (NO_3^--N)
- Ammonia-nitrogen (NH_3-N)
- Total Kjeldahl Nitrogen (TKN)
- Total Phosphorus (TP)
- Total Suspended Solids (TSS)
- Biological Oxygen Demand (BOD)
- Chemical Oxygen Demand (COD)
- *Escherichia coli* bacteria (*E. coli*)

Description of Parameters Monitored

Comprehensive evaluations of stream water quality require collecting data on a variety of different water quality parameters. A brief description of each parameter monitored for this project is as follows:

Temperature
Temperature can determine the form, solubility, and toxicity of a broad range of aqueous compounds. Likewise, water temperature regulates the species composition and activity of life associated with the aquatic environment. Since essentially all aquatic organisms are 'cold-blooded' the temperature of the water regulates their metabolism and ability to survive and reproduce effectively (EPA, 1976). The Indiana Administrative Code (327 IAC 2-1-6) sets maximum temperature limits for Indiana streams. Temperatures should not exceed 10.0 ^{o}C by more than 1.7 ^{o}C during the month of January and 21.1 ^{o}C during the month of April. (Water quality sample collection for this assessment occurred in these two months.) At no time should water temperatures exceed 32.2 ^{o}C. In addition, the Indiana Administrative Code states that "the maximum temperature rise at any time or place…shall not exceed 2.8 ^{o}C in streams and 1.7 ^{o}C in lakes and reservoirs."

Oxygen
Like their terrestrial counterparts, aquatic fauna require oxygen to live. During respiration, aquatic fauna consume oxygen in the water column. The degradation of certain organic substances also utilizes oxygen in the water column. Much of the oxygen in the water column originates from the air above the water body. Plants (rooted and algae) also produce oxygen as a byproduct of photosynthesis. Occasionally, excessive algae growth can over-saturate a waterbody with oxygen.

Water quality researchers and monitoring programs often measure the amount of oxygen in the water and the potential substances in the waterbody to utilize this oxygen. Dissolved oxygen (DO) is a measure of how much oxygen is in the water, while biochemical oxygen demand (BOD) and chemical oxygen demand (COD) are measures of the potential for oxygen depletion in a waterbody. Specifically, BOD is a measure of the amount of oxygen consumed by microorganisms in a water sample over a 5-day period; COD is a measure of all the oxidizable wastes in a given water quality sample. Although the COD analysis is easier to conduct than the BOD analysis, it includes some organic wastes that do not typically contribute to the oxygen demand of a stream (Schueler, 1997). A variety of sources contribute oxygen demanding organic wastes to a stream, including soil erosion, human/animal waste, vehicle emissions, household or industrial chemicals, lawn clippings, and pesticides (Horner et al., 1994).

The amount of DO in a lake can affect a variety of chemical reactions in the water. For example, in many lakes, particularly lakes that stratify (become layered due to differences in temperature along the lake's depth gradient), decomposition processes that use up available oxygen coupled with limited mixing with the oxygenated upper layer of the lake lead to a lack of oxygen in the lake's lower water layer. Without the presence of oxygen, phosphorus bound to the lake sediments may be released into the water column. The phosphorus is released as soluble reactive phosphorus (SRP), the form that is readily used by algae. The lack of oxygen also prevents the conversion of ammonium to nitrate. Thus, more of the usable form of nitrogen is available for algae growth.

The Indiana Administrative Code (IAC) requires that all waterbodies possess a daily dissolved oxygen average concentration of at least 5 mg/L and that at no time shall the DO concentration drop below 4 mg/L. The State set these standards to ensure aquatic life survival. In addition, DO concentrations above 1 mg/L are necessary to prevent the release of phosphorus from the bottom sediments. These thresholds should be considered when using DO to evaluate the aquatic ecosystem health.

pH

The pH of water describes the concentration of acidic ions (specifically $H+$) present in water. The pH also determines the form, solubility, and toxicity of a wide range of other aqueous compounds. The IAC establishes a range of 6 to 9 pH units for the protection of aquatic life. pH concentrations in excess of 9 are acceptable when occurring as daily fluctuations associated with photosynthetic activity.

Conductivity

Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions, on their total concentration, mobility, and valence (APHA, 1995). At low discharge, conductivity is higher than following storm events because the water moves more slowly across or through ion-containing soils and substrates during base flow. Carbonates and other charged particles dissolve into the slow-moving water, thereby increasing the conductivity of a water body.

The Indiana Administrative Code standard for conductivity is reported as 750 mg/L of dissolved solids. Multiplying the dissolved solids concentrations by a conversion factor of 0.55 to 0.75 ɥmhos per mg/L of dissolved solids roughly converts dissolved solid concentrations to specific conductance (Allan, 1995). Multiplying 750 mg/L by the conversion factor range yields a specific conductance range of approximately 1000 to 1360 ɥmhos.

Nutrients (Nitrogen and Phosphorus)
Nutrients are a necessary component of aquatic ecosystems. Ecosystem primary producers (i.e. plants) require nutrients for growth. Growth of the primary producers ultimately supports the remainder of the organisms in the ecosystem's food web. Insufficient nutrient levels in stream and lake water can limit the size and complexity of biological communities living in the stream or lake. In contrast, excessive levels of nutrients in lake or stream water alter biological communities by promoting nuisance species growth. For example, high concentrations of total phosphorus in lake water (>0.03 mg/L) create ideal conditions for nuisance algae growth. In extreme cases, lake algae growth can exclude rooted macrophyte growth and shift fish community composition.

In low to middle order streams such as Duck Creek, Turkey Creek, and Deep River, aquatic plants exist primarily as periphyton. Light availability and flow regime limit the establishment of rooted macrophytes and phytoplankton populations that are more common in lakes and large river systems. As small stream ecosystems' primary producers, periphyton support higher members of the stream food web (invertebrates, fish). Nutrients are one of the factors that limit periphyton growth in streams and thus are included in stream water chemistry analyses.

Phosphorus and nitrogen are common nutrients governing plant growth. (When diatoms dominate the periphyton or planktonic community, silica is also an important nutrient.) Sources of phosphorus and nitrogen include fertilizers, human and animal waste, atmospheric deposition in rainwater, and yard waste or other plant material that reaches streams. Nitrogen can also diffuse from the air into streams. Atmospheric nitrogen is then "fixed" by certain algae species (cyanobacteria) into a usable form of nitrogen. Because of this readily available source of nitrogen (via the air), phosphorus is usually the "limiting nutrient" in aquatic ecosystems.

Phosphorus and nitrogen exist in several forms in water. The two common phosphorus forms are soluble reactive phosphorus (SRP) and total phosphorus (TP). SRP is the dissolved form of phosphorus. It is the form that is "usable" by algae. Algae cannot directly digest and use particulate phosphorus for growth. Total phosphorus is a measure of both dissolved and particulate forms of phosphorus. The most commonly measured nitrogen forms are nitrate-nitrogen (NO_3), ammonium-nitrogen (NH_4^+), and total Kjeldahl nitrogen (TKN). Nitrate is a dissolved form of nitrogen that is commonly found in surface water where oxygen is readily available. In contrast, ammonium-nitrogen is generally found in water where oxygen is lacking. Like SRP, ammonium is a dissolved form of nitrogen and the one utilized by algae for growth. The TKN measurement parallels the TP measurement to some extent. TKN is a measure of the total organic nitrogen (particulate) and ammonium-nitrogen in the water sample.

Indiana possesses nitrate-nitrogen and ammonia-nitrogen standards for its water bodies. These standards apply to all state water bodies except those designated as Limited Use waters. The nitrate-nitrogen standard is 10 mg/L; nitrate-nitrogen concentrations exceeding 10 mg/L in drinking water are considered hazardous to human health (Indiana Administrative Code IAC 2-1-6). Because both temperature and pH govern the toxicity of ammonia for aquatic life, these factors are weighted in the ammonia the standard. According to the IAC, maximum unionized ammonia concentrations within the temperature and pH ranges measured for the study streams should range between 0.022-0.076 mg/L.

Total Suspended Solids

Total suspended solids (TSS) refer to all particles suspended or dissolved in stream water. Sediment, or dirt, is the most common solid suspended in stream water. The sediment in stream water originates from many sources, but a large portion of sediment entering streams comes from active construction sites or other disturbed areas such as unvegetated stream banks.

Suspended solids impact streams in a variety of ways. When suspended in the water column, solids can clog the gills of fish and invertebrates. As the sediment settles to the creek bottom, it covers spawning and resting habitat for aquatic fauna, reducing the animals' reproductive success. Suspended sediments also impair the aesthetic and recreational value of a waterbody. In lakes and reservoirs, sediment accumulation limits boating opportunities and shortens the waterbody's lifespan. Similarly, few people are enthusiastic about having a picnic near a muddy creek or wading in silty water. Pollutants attached to sediment also degrade water quality.

Pathogens

Bacteria, viruses, and other pathogens are contaminants of concern in urban watersheds. Common sources of these pathogens include human and wildlife waste, fertilizers containing manure, previously contaminated sediments, septic tank leachate, combined sewer overflows, and illicit connections to stormwater sewers. Pathogenic organisms can present a threat to human health by causing a variety of serious diseases, including infectious hepatitis, typhoid, gastroenteritis, and other gastrointestinal illnesses. Thus, pathogens can impair the recreational value of a stream. Some pathogens can also impair biological communities. Water quality researchers and monitoring programs utilize *E. coli* as an indicator for the presence of pathogens in water. According to the IAC, *E. coli* concentrations should not exceed 235 colonies/100 mL in any one sample within a 30-day period.

Water Quality Monitoring Results

Introduction

There are two useful ways to report water quality data in flowing water. Concentrations express the mass of a substance per unit volume, for example milligrams of total suspended solids per liter (mg/L). Mass loading describes the mass of a particular material being carried per unit time (kg/d). Loading is important when comparing among sites and among sampling dates because: 1) Flow can be highly variable; therefore, normalizing concentrations to flow eliminates variability and 2) Delivery of materials is important to consider. For example, a stream with high discharge but low pollutant concentration may deliver a larger portion of a pollutant to its receiving body than a stream with higher pollutant concentration but lower discharge.

The total amount of nutrients, suspended solids, and pathogens entering the stream is of greatest concern when considering the effects of these materials downstream. Because consideration of concentration and mass loading data is important, the following sections will discuss 1) physical parameter concentrations, 2) chemical and bacterial parameter concentrations, and 3) chemical and sediment parameter mass loading.

Physical Parameter Concentrations

Table 5-2 presents the physical parameter results measured during base flow and storm flow. The following discussion addresses these physical parameters. During base flow sampling, temperatures in the streams varied from 37º F (3º C) at Sites 1 (Deep River), 2 (Duck Creek), and 3 (Deep River) to 43º F (6º C) at Site 9 (Turkey Creek). Water temperatures during storm flow varied from 41º F (5º C) to 43º F (6º C) at all sampling sites.

Dissolved oxygen (DO) concentrations varied from 9.2 mg/L to 12.2 mg/L. DO in all streams exceeded the Indiana state minimum standard of 5 mg/L indicating that oxygen was sufficient to support aquatic life. Since DO varies with temperature (cold water can hold more oxygen than warm water), it is also important to examine DO saturation values. DO saturation refers to the amount of DO dissolved in water compared to the total amount possible when equilibrium between the stream water and the atmosphere is achieved. Stream dissolved oxygen concentrations that are less than 100% saturated imply one of two things: decomposition processes within the stream consume oxygen more quickly than it can be replaced or flow in the stream is not turbulent enough to entrain sufficient oxygen.

Table 5-2. Physical parameter data collected during stream chemistry sampling events in the Deep River watershed on 1/28/2002 and 4/3/2002. A double dash (--) indicates that no sample collection occurred at that site.

Site	Date	Timing	Flow (cfs)	Temp (ºC)	DO (mg/L)	DO Sat (%)	Conductivity (ɥmhos/cm)	pH (SU)	BOD (mg/L)
1	1/28/2002	Base	53.43	3.0	12.20	92.0	900	6.9	2.3
	4/3/2002	Storm	525.99	6.0	10.72	84.9	900	8.1	<2.0
2	1/28/2002	Base	5.79	3.0	11.10	85.0	700	8.1	<2.0
	4/3/2002	Storm	78.83	5.0	9.70	75.3	400	8	<2.0
3	1/28/2002	Base	40.65	3.0	12.20	92.0	900	8.1	<2.0
	4/3/2002	Storm	592.52	7.0	10.96	89.4	900	8.5	<2.0
4	1/28/2002	Base	41.27	3.5	11.60	90.0	800	8.4	<2.0
	4/3/2002	Storm	633.50	6.0	9.98	78.5	500	7.8	4
5	1/28/2002	Base	8.32	5.5	9.20	75.0	900	8.3	<2.0
	4/3/2002	Storm	139.13	6.0	9.88	78.7	700	8.5	2.8
6	1/28/2002	Base	18.11	5.0	11.00	88.0	800	8.4	<2.0
	4/3/2002	Storm	335.34	6.0	9.95	79.1	400	8.5	3.2
7	1/28/2002	Base	0.75	5.5	10.80	88.0	1200	8.2	<2.0
	4/3/2002	Storm	--	--	--	--	--	--	--
8	1/28/2002	Base	1.30	5.0	11.20	90.0	700	8.1	3.6
	4/3/2002	Storm	364.17	6.0	10.56	83.8	500	8.7	3.3
9	1/28/2002	Base	11.25	6.0	10.80	89.0	800	6.8	<2.0
	4/3/2002	Storm	87.48	6.0	10.01	80.5	700	8.1	3.4

Stream data indicate that saturated dissolved oxygen conditions did not occur at any of the sample sites. Saturation ranged from 75% at Site 5 (Turkey Creek) to 92% at Sites 1 (Deep River Mouth) and 3 (Deep River at Lake George Dam). The slow glide (long, slow moving pool) habitat that exists at Site 5 likely plays a larger role in limiting dissolved oxygen content at that site than decomposition processes since BOD concentrations were below the detection limit at the time of sampling. In contrast, the Lake George spillway provides an excellent opportunity for oxygen to become entrained in water. Water collected below the Lake George dam (Site 3) contained a higher percentage of oxygen compared to other sites. Under storm flow conditions, water at Sites 2, 4, 5, and 6 exhibited the lowest dissolved oxygen content. At Sites 4, 5, and 6 the low dissolved oxygen saturation accompanied high (relative to other sites in the watershed) BOD concentrations. Given the high BOD concentrations, decomposition processes likely played a role in lowering the DO content of the water at these three sites. Site 3 exhibited the highest DO saturation during storm flow conditions. Again the proximity of Site 3 to the Lake George spillway is likely responsible for the relatively high DO saturation observed in the water.

In general, both conductivity and pH values fell within acceptable ranges. Conductivity values in Deep River watershed streams ranged from 700 to 1200 µmhos during base flow, and 400 to 900 µmhos during storm flow. All of these measurements fell below the upper end of the range and most fell below the lower end of the range obtained by converting the IAC dissolved solids standard to specific conductance. For the most part, conductivity measured during storm flow was lower than conductivity measured during base flow. Higher flows tend to dilute ion concentrations and do not allow enough time for soil ion dissolution to occur. Values of pH fell within the range of 6-9 units established as acceptable by the IAC for warm water aquatic life. On a site-by-site basis, pH levels during storm flow were generally greater than those measured during base flow.

BOD levels were relatively low in the Deep River/ Turkey Creek watershed. During base flow, seven of the nine sites exhibited BOD values below the detection limit. Sites 1 and 8 had BOD concentrations of 2.3 mg/L and 3.6 mg/L, respectively. Under storm flow conditions, five of the nine sites exhibited BOD concentrations above the detection limit with the highest concentration observed at Site 4 (4 mg/L). The high BOD levels observed at Site 4 following the storm event likely resulted from a flushing of the wetland immediately upstream of Site 4. If storm flow is of sufficient magnitude, the force of the water may scour out organic material previously trapped in the wetland.

BOD levels are consistent with levels found in other Indiana streams. In a review of selected Indiana streams (IDEM 1991 data), White (unpublished) found the average BOD concentration to be 2.2 mg/L. Most Indiana streams possessed BOD concentrations between 1.1 mg/L and 3.3 mg/L. Recent IDEM data suggests that White's average is still applicable. The average BOD concentration reported at IDEM fixed monitoring stations from 1995 to 2000 was 2.5 mg/L (IDEM, unpublished). The median concentration was 1.9 mg/L.

Chemical and Bacterial Parameter Concentrations

Table 5-3 lists the chemical and bacterial concentration data for Deep River watershed streams by site. **Figures 5-4 to 5-10** present concentration information graphically. Again, because the data objective goals for the water quality assessment were to obtain relative measures of non-point source pollutants, the following discussion again focuses on a comparison of concentrations found at the sampling sites in the watershed rather than the raw data itself. However, to provide larger context for understanding the water quality data, **Table 5-4** presents the minimum, maximum, average, and median values for selected water quality parameters collected at IDEM fixed monitoring stations from 1995 to 2000.

Figure 5-5 presents the nitrate-nitrogen concentration data for both base and storm flow conditions. Nitrate-nitrogen concentrations were relatively low. Only two of the sites exceeded the median concentration reported at the IDEM fixed monitoring stations. Nitrate-nitrogen concentrations measured during base flow sampling were greater than concentrations measured in storm flow samples at all but three sample sites (Sites 4, 5, and 9). Duck Creek (Site 2) exhibited the highest nitrate-nitrogen concentration (2.37 mg/L), while Turkey Creek (Site 9) possessed the lowest nitrate-nitrogen concentration (0.19 mg/L). Concentrations at all sites remained below 10 mg/L, the concentration set by the IAC for safe drinking water.

Table 5-3. Chemical and bacterial data for Deep River watershed streams collected during stream chemistry sampling events on 1/28/2002 and 4/3/2002.

Site	Date	Timing	NO_3^--N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)	*E. coli* (col/100 mL)
1	1/28/2002	Base	1.62	0.07	1.30	0.17	5.2	48
	4/3/2002	Storm	0.55	0.39	0.55	<0.10	43.0	180
2	1/28/2002	Base	2.37	0.04	1.00	<0.10	22.0	140
	4/3/2002	Storm	1.20	0.13	1.20	0.24	48.0	760
3	1/28/2002	Base	1.53	0.07	1.60	0.14	14.0	42
	4/3/2002	Storm	0.71	0.36	0.71	<0.10	29.0	80
4	1/28/2002	Base	0.88	0.10	1.00	<0.10	18.0	48
	4/3/2002	Storm	1.10	0.27	1.10	0.26	150.0	800
5	1/28/2002	Base	0.21	0.10	1.10	<0.10	13.0	94
	4/3/2002	Storm	0.77	0.16	0.77	0.11	56.0	440
6	1/28/2002	Base	1.75	0.24	1.80	<0.10	8.4	24
	4/3/2002	Storm	1.00	0.31	1.00	0.28	120.0	1000
7	1/28/2002	Base	0.36	<0.01	0.71	<0.10	<5.0	50
	4/3/2002	Storm	--	--	--	--	--	--
8	1/28/2002	Base	2.23	1.50	5.20	0.18	<5.0	110
	4/3/2002	Storm	1.30	0.40	1.30	0.30	120.0	2100
9	1/28/2002	Base	0.19	0.15	1.30	<0.10	8.0	480
	4/3/2002	Storm	0.71	0.36	0.71	0.10	62.0	310

Table 5-4. The minimum, maximum, average and median values for selected water quality parameters collected at IDEM fixed monitoring stations from 1995 to 2000.

	TSS (mg/L)	TKN (mg/L)	NO_2+NO_3 (mg/L)	NH_3 (mg/L)	TP (mg/L)	BOD (mg/L)	COD (mg/L)
Minimum	2	0.0	0.04	0.0	0.03	0.0	3.9
Maximum	836	16.0	32.0	13.0	38.4	32	234
Median	19	0.7	2.1	0.2	0.14	1.9	16.4
Average	37	0.86	2.9	0.3	0.2	2.5	18.4

Figure 5-5. Nitrate-nitrogen concentrations measured in Deep River water quality samples collected on 1/28/2002 and 4/3/2002. No storm flow sample collection occurred at Site 7.

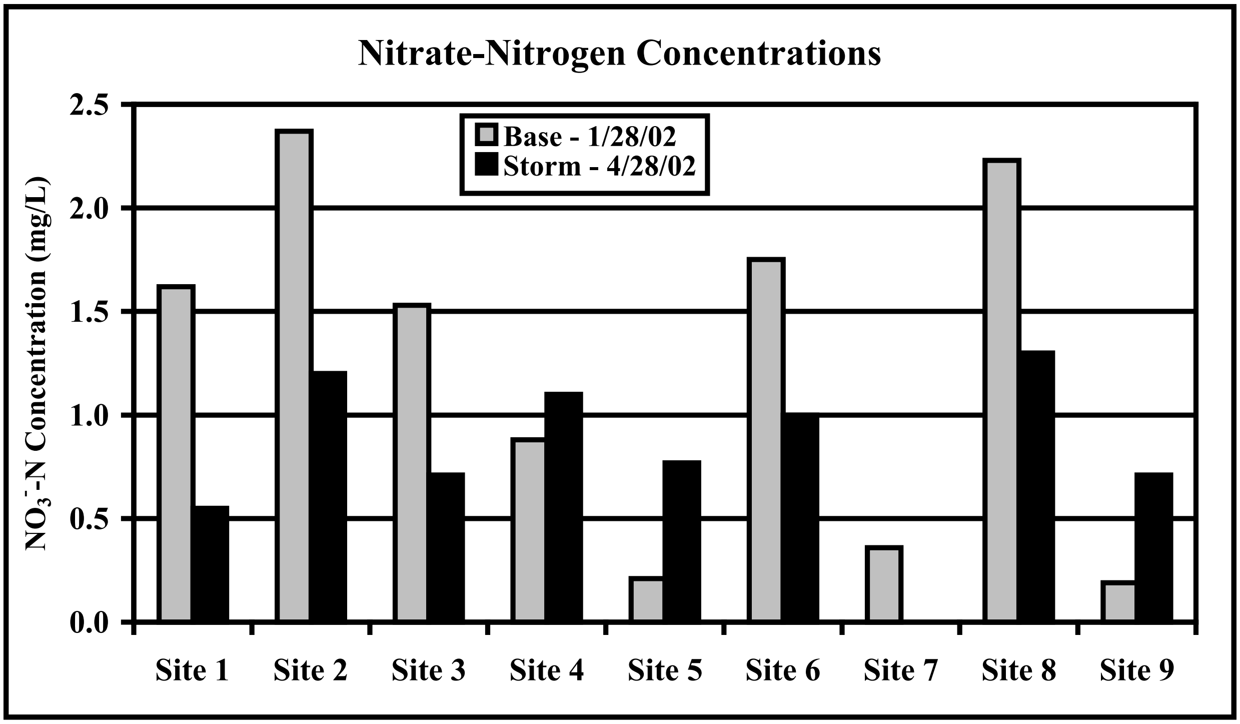
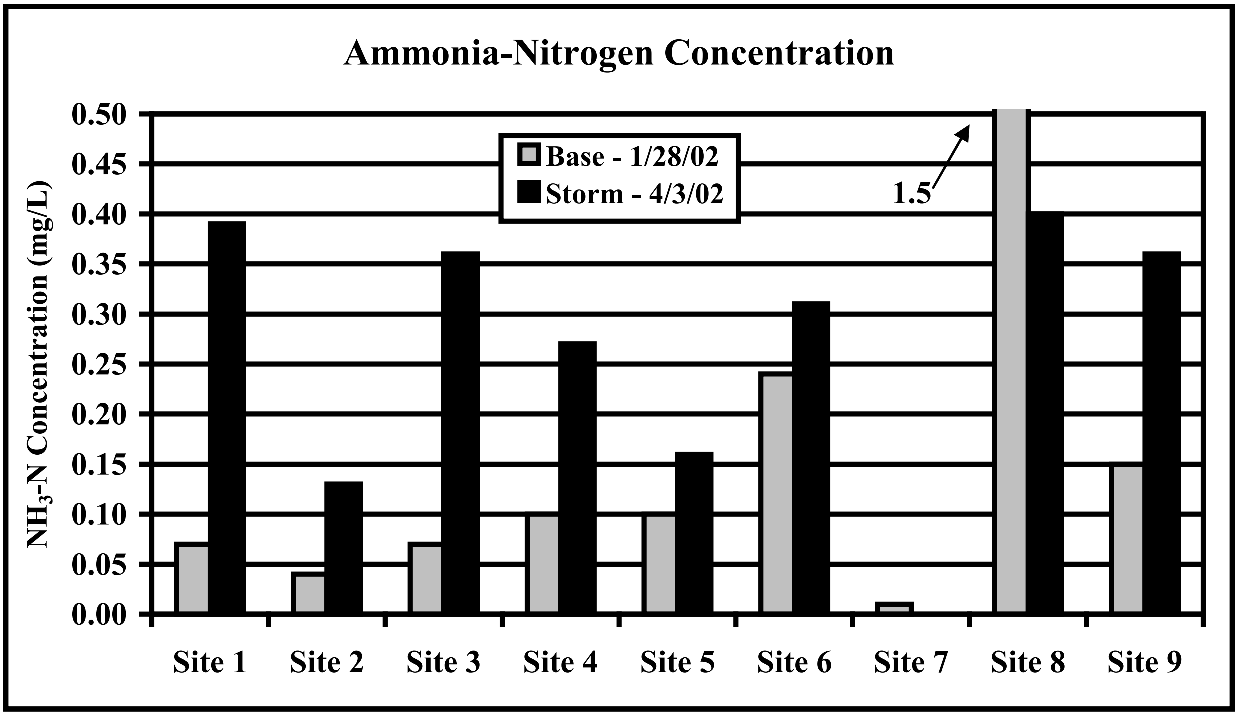


Figure 5-6 presents the ammonia-nitrogen data concentration. During base flow conditions, all Sites except Site 8 possessed low concentrations relative to the IDEM reported median concentration of ammonia-nitrogen. Several of the sites exceeded the IDEM reported median concentration of ammonia-nitrogen during storm flow conditions, but not by a great amount. Ammonia-nitrogen concentrations measured during base flow sampling were lower than concentrations measured in storm flow samples at all but one sample site (Sites 8). The base flow sample collected at the Deep River County Park (Site 8) exhibited the highest ammonia-nitrogen concentration (1.5 mg/L), while the Deep River tributary (Site 7) base flow sample possessed the lowest ammonia-nitrogen concentration (<0.01 mg/L). None of the base flow concentrations exceeded the IAC ammonia-nitrogen standard for the protection of aquatic life. In contrast, all sites sampled during the storm event exceeded the IAC standard.

Figure 5-6. Ammonia-nitrogen concentrations measured in Deep River water quality samples collected on 1/28/2002 and 4/3/2002. No storm flow sample collection occurred at Site 7.



Unlike the dissolved parameters, many of the Sites' total Kjeldahl nitrogen (TKN) concentrations exceeded the median concentration found at IDEM fixed monitoring stations (See **Figure 5-7**). Generally, TKN concentrations measured during base flow sampling exceeded the concentrations measured in storm flow samples. The base flow sample collected at the Deep River County Park (Site 8) possessed the highest TKN concentration (5.2 mg/L). Although ammonia was also elevated at this site, the presence of particulate organic nitrogen pollutants is likely here.

Figure 5-7. Total Kjeldahl nitrogen (TKN) concentrations measured in Deep River water quality samples collected on 1/28/2002 and 4/3/2002. No storm flow sample collection occurred at Site 7.

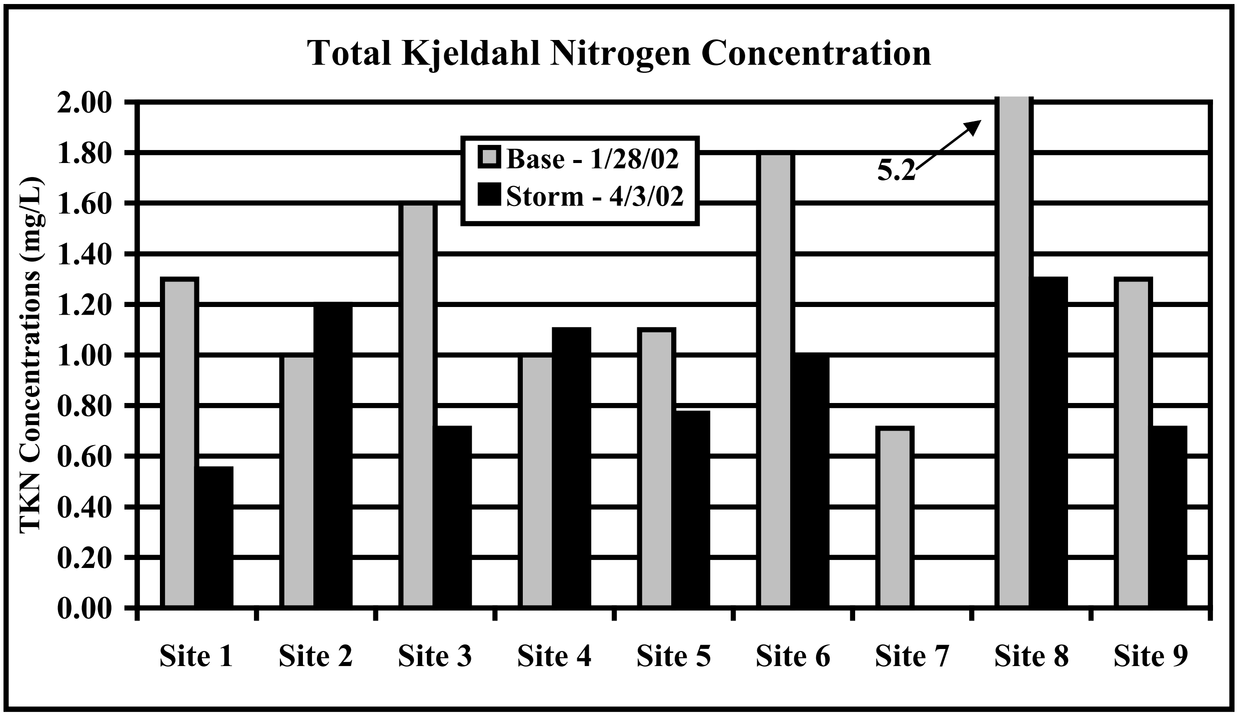


Figure 5-8 shows the total phosphorus concentration data for the sampling sites. Under base flow conditions, total phosphorus concentrations were generally low with six of the nine sites exhibiting total phosphorus concentrations below the laboratory detection limit. At six of the Sites, total phosphorus concentrations measured during storm flow sampling exceeded concentrations measured in base flow samples. Higher overland flow velocities typically results in the increase in sediment particles and the particulate phosphorus associated with them in runoff. Additionally, greater streambank and streambed erosion occurs during high flow. Therefore, higher concentrations of particulate phosphorus are typically measured in storm flow samples. Only Site 1 and Site 3 exhibited storm flow total phosphorus concentrations below those measured during base flow. The sample collected at the Deep River County Park (Site 8) contained the highest total phosphorus concentration (0.30 mg/L).

Figure 5-8. Total phosphorus (TP) concentrations measured in Deep River water quality samples collected on 1/28/2002 and 4/3/2002. Although many samples are graphically displayed with concentrations of 0.10 mg/L, all of these except Site 9 during storm flow are actually below the laboratory detection level of 0.10 mg/L. They are only included for visual comparison purposes. No storm flow sample collection occurred at Site 7.

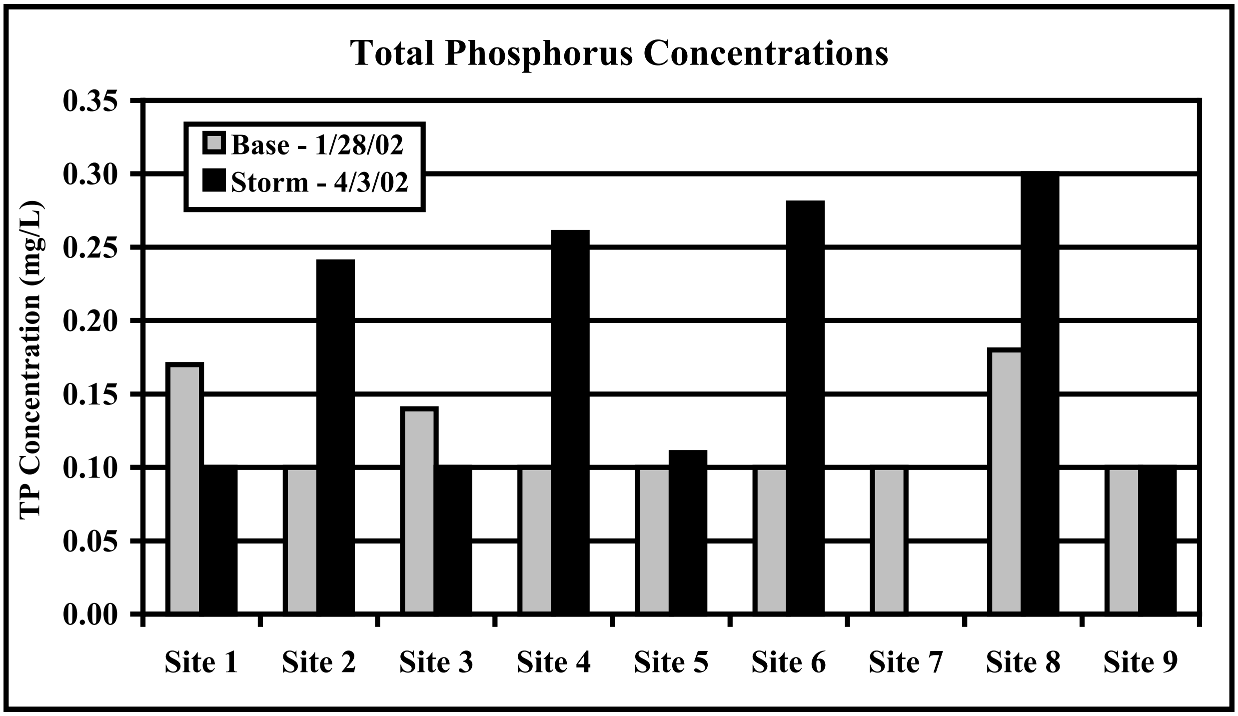


Figure 5-9 presents the total suspended solid (TSS) concentration data for the study streams. Total suspended solids concentrations measured during storm flow sampling exceeded concentrations measured in base flow samples at all sample sites. As noted in the total phosphorus discussion, higher overland flow velocities typically result in the increase in sediment particles in runoff. Greater streambank and streambed erosion occurs during high flow as well. Therefore, higher concentrations of suspended solids are typically measured in storm flow samples. The storm flow sample collected in Lake George (Site 4) contained the highest recorded total suspended solids concentration (150 mg/L); storm flow samples collected at Sites 6 (Turkey Creek) and 8 (Deep River County Park) contained the second highest TSS concentrations (120 mg/L). High TSS concentrations at Site 4 following a storm event may have resulted from the flushing of previously settled sediment in the wetland upstream of Site 4. Storm flow sample concentrations at Sites 4, 6, and 8 exceeded 80 mg/L, the concentration found to be deleterious to aquatic life (Waters, 1995).

Figure 5-9. Total suspended solids (TSS) concentrations measured in Deep River water quality samples collected on 1/28/2002 and 4/3/2002. No storm flow sample collection occurred at Site 7.

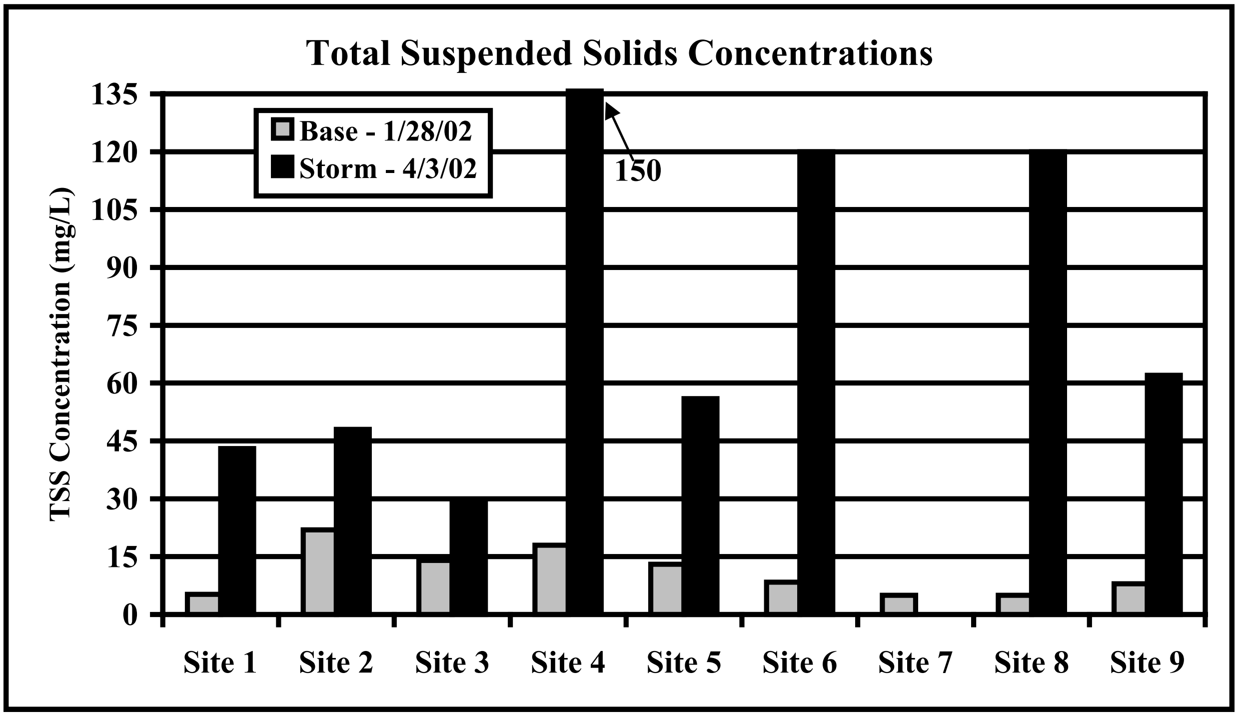
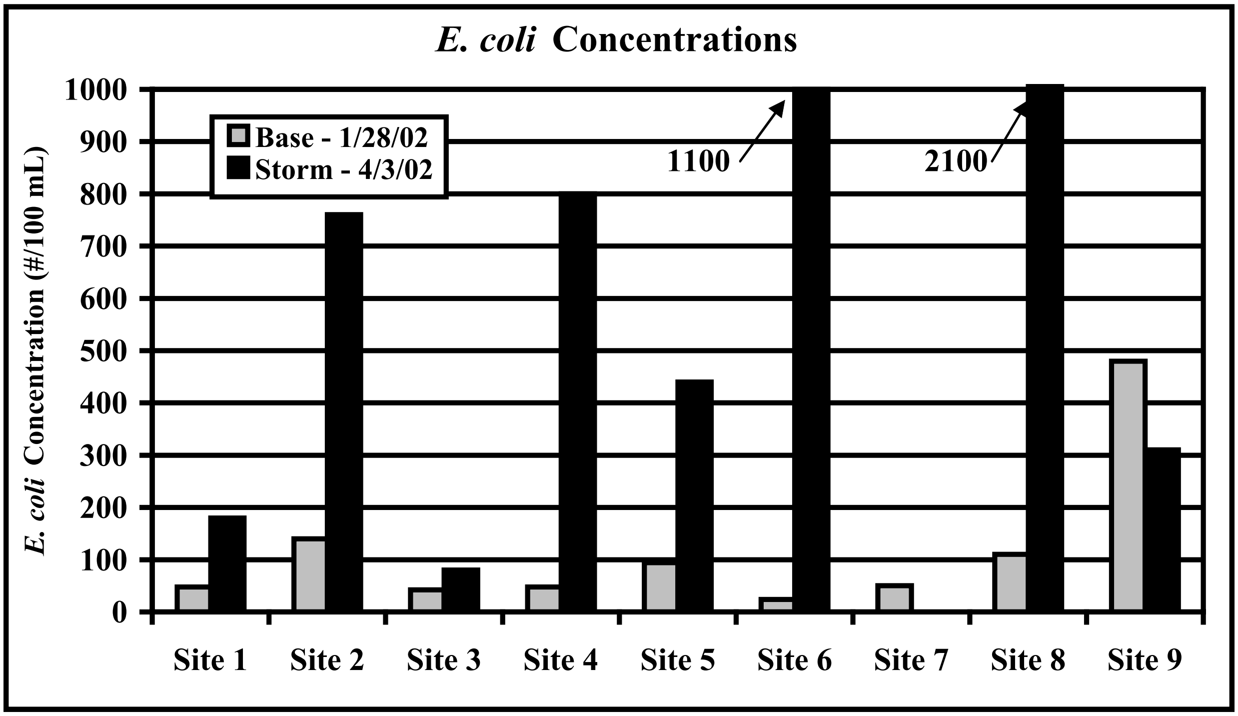


Figure 5-10 displays the *E. coli* concentration data for the two sampling events. As expected, the *E. coli* concentrations observed during base flow conditions were low. High *E. coli* concentrations were not likely given the low water temperature. Despite this, the *E. coli* concentration at Site 9 exceeded the state standard (235 col/100 mL) for state waters. *E. coli* concentrations measured during storm flow sampling exceeded concentrations measured in base flow samples at all sites except at Site 9. The storm flow sample collected at the Site 8 possessed the highest *E. coli* concentration (2100 colonies/100 mL), while Site 3 exhibited the lowest storm flow *E. coli* concentration (24 colonies/100 mL). During storm flow conditions, only two sample sites, Site 1 and Site 3, exhibited *E. coli* concentrations below the state standard. Low *E. coli* concentrations downstream of Lake George are likely the result of the exposure to ultraviolet light afforded to the water in the lake. Relative to other streams in the state, the storm water *E. coli* concentrations in the Deep River/ Turkey Creek watershed are similar or slightly low. White (unpublished) found the average *E. coli* concentration in Indiana streams to be approximately 650 colonies/100 mL. Only Site 8 possessed an *E. coli* concentration significantly above this value (p=0.05).

Figure 5-10. *E. coli* concentrations measured in Deep River water quality samples collected on 1/28/2002 and 4/3/2002. No storm flow sample collection occurred at Site 7.



Chemical and Sediment Parameter Mass Loading

Table 5-5 lists the chemical and sediment mass loading data for Deep River/ Turkey Creek watershed by site. **Figures 5-10 to 5-14** present mass loadings information graphically.

Table 5-5. Chemical and sediment loading data for Deep River watershed streams collected during stream chemistry sampling events on 1/28/2002 and 4/3/2002.

Site	Date	Timing	NO_3^--N (kg/d)	NH_3-N (kg/d)	TKN (kg/d)	TP (kg/d)	TSS (kg/d)
1	1/28/2002	Base	2,451.3	9.2	170.0	22.2	679.8
	4/3/2002	Storm	29,494.2	501.9	707.9	<128.7	55,341.8
2	1/28/2002	Base	388.6	0.6	14.2	<1.42	311.6
	4/3/2002	Storm	9,844.6	25.1	231.5	46.3	9,247.9
3	1/28/2002	Base	1,761.3	7.0	159.1	13.9	1,392.5
	4/3/2002	Storm	260,009.0	521.9	1,029.4	<145.0	42,044.0
4	1/28/2002	Base	1,028.5	10.1	101.0	<0.36	1,817.7
	4/3/2002	Storm	30,678.6	418.5	1,705.1	403.0	232,511.7
5	1/28/2002	Base	49.5	2.0	22.4	<2.03	264.7
	4/3/2002	Storm	4,885.8	54.5	262.1	37.5	19,064.1
6	1/28/2002	Base	897.4	10.6	79.8	<4.4	372.2
	4/3/2002	Storm	20,988.0	254.4	820.5	229.8	98,463.1
7	1/28/2002	Base	7.6	<0.02	1.3	<0.2	<9
	4/3/2002	Storm	--	--	--	--	--
8	1/28/2002	Base	82.0	4.8	16.5	0.6	<16
	4/3/2002	Storm	30,733.6	356.4	1,158.4	267.3	1,206,928.2
9	1/28/2002	Base	60.5	4.1	35.8	<2.8	220.2
	4/3/2002	Storm	2,997.6	77.1	152.0	21.4	13,270.7

Figure 5-10. Nitrate-nitrogen loading in Deep River water quality samples collected on 1/28/2002 and 4/3/2002. No storm flow sample collection occurred at Site 7.

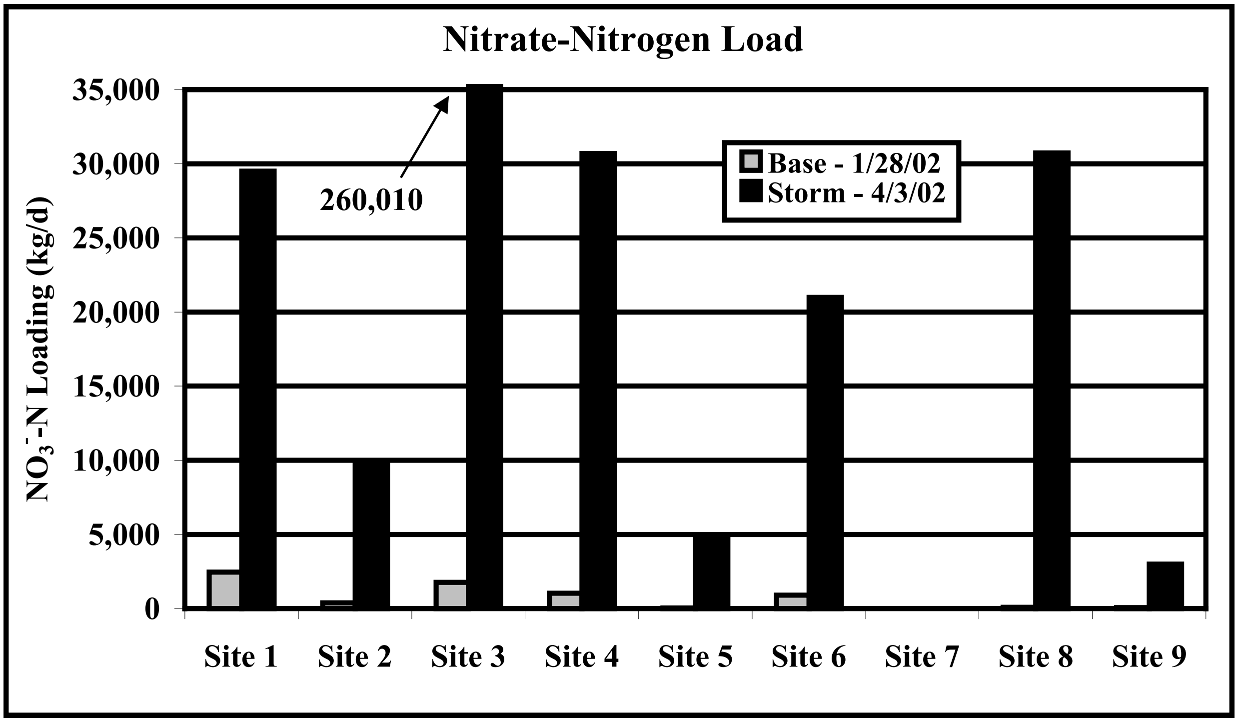


Figure 5-11. Ammonia-nitrogen loading in Deep River water quality samples collected on 1/28/2002 and 4/3/2002. No storm flow sample collection occurred at Site 7.

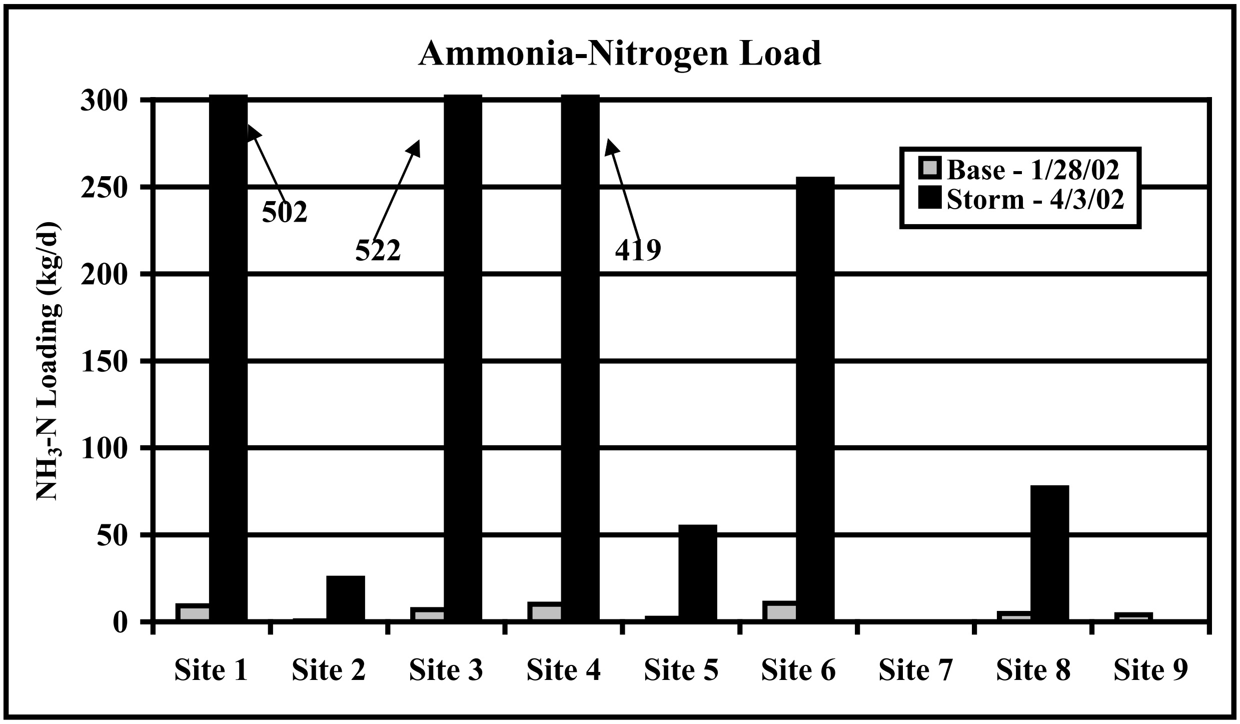


Figure 5-12. Total Kjeldahl nitrogen loading in Deep River water quality samples collected on 1/28/2002 and 4/3/2002. No storm flow sample collection occurred at Site 7.

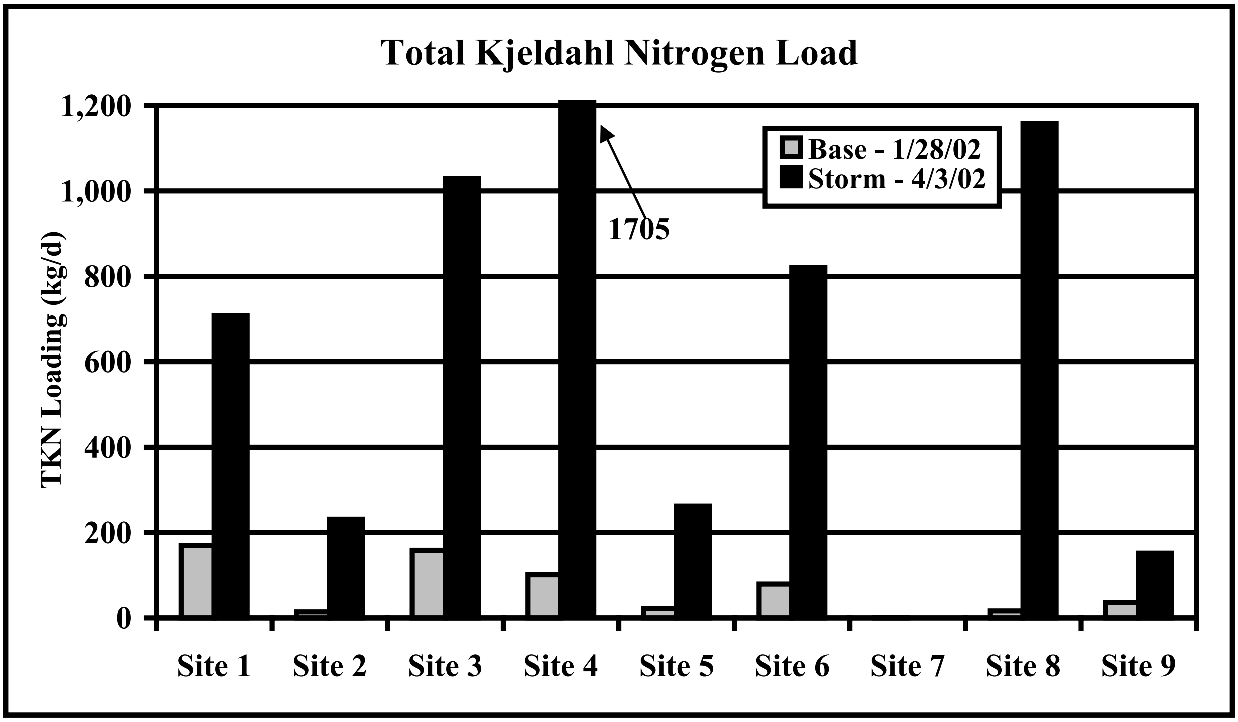


Figure 5-13: Total phosphorus loading in Deep River water quality samples collected on 1/28/2002 and 4/3/2002. No storm flow sample collection occurred at Site 7.

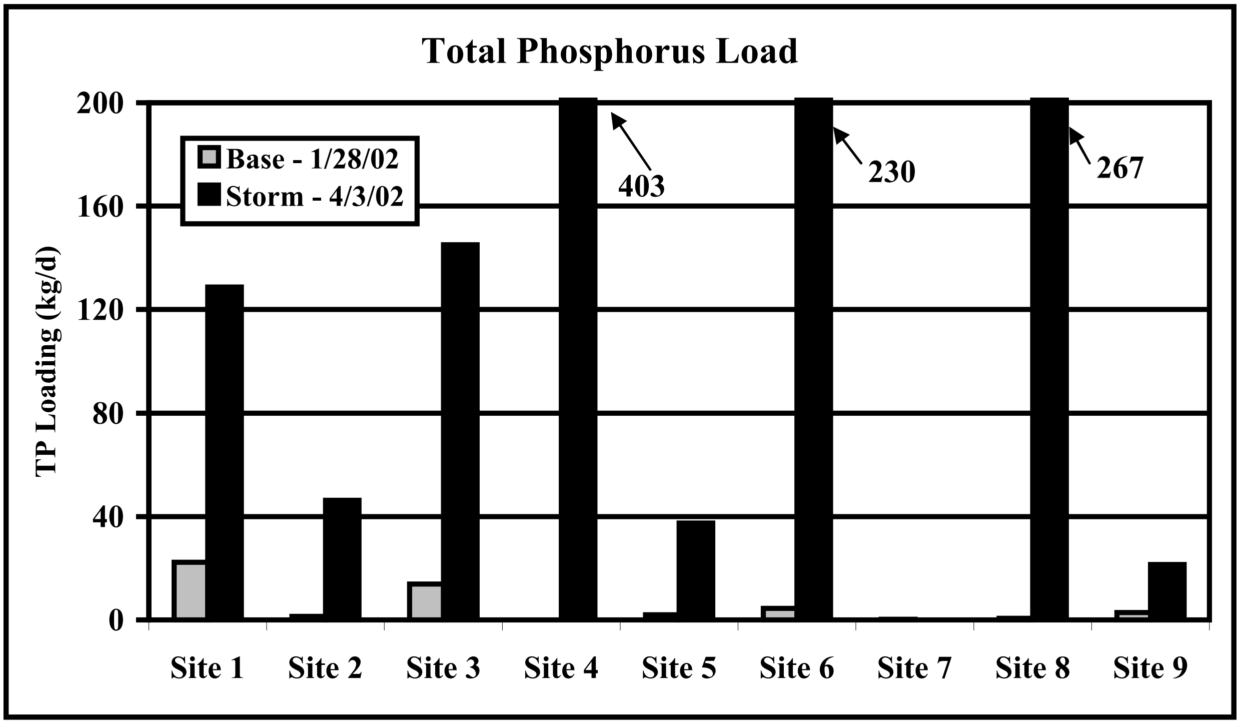
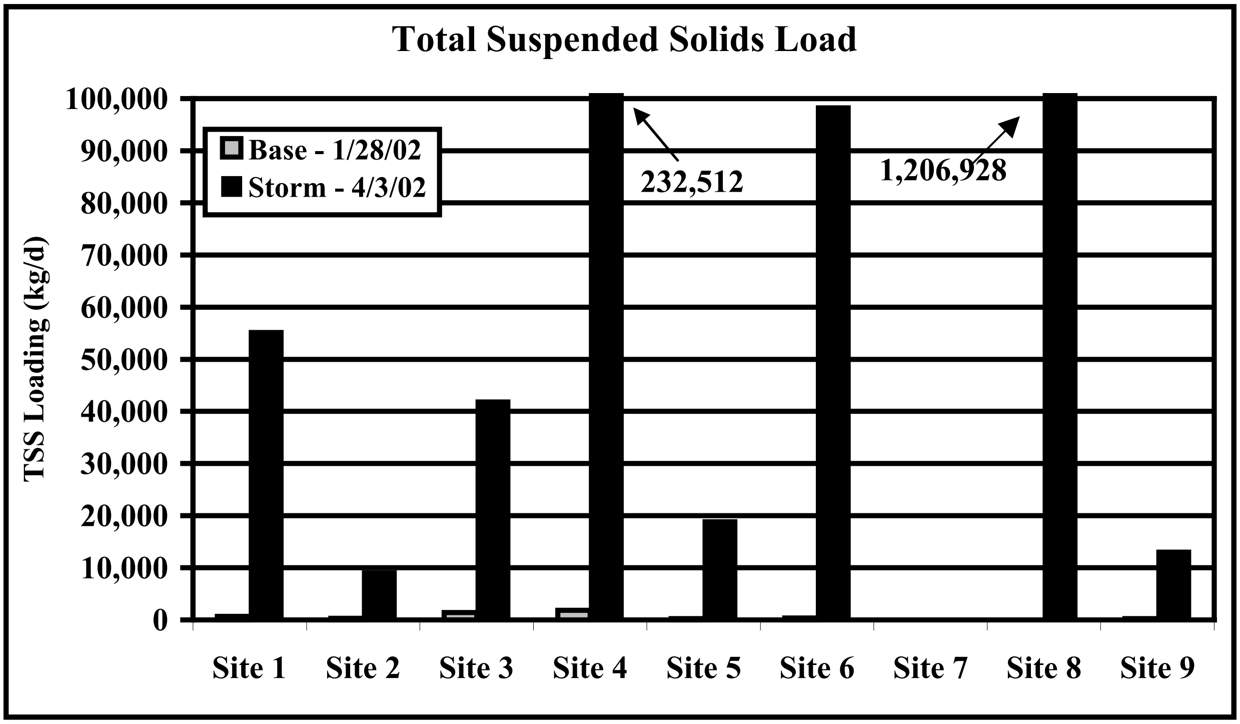


Figure 5-14: Total suspended solids loading in Deep River water quality samples collected on 1/28/2002 and 4/3/2002. No storm flow sample collection occurred at Site 7.



Under base flow conditions, Site 1 possessed the greatest load of nitrate-nitrogen, total Kjeldahl nitrogen, and total phosphorus. This is to be expected. As the site located furthest downstream, Site 1 receives the pollutants from all the other sites. In contrast, Site 4 possessed the greatest load of total suspended solids. The decrease in load observed in Site 3 indicates that the lake is trapping sediment. It is important to note that the total suspended solid load decreases further at Site 1, suggesting additional deposition occurs between the Lake George dam and Site 1.

Under storm flow conditions, Site 3 possessed the greatest nitrate-nitrogen and ammonia-nitrogen loads. Site 4 exhibited the greatest total Kjeldahl nitrogen and total phosphorus loads. High TKN and total phosphorus loads suggest organic matter may be flushed from the wetland in the southwest corner of Lake George. Similarly, the high total suspended solid load at this point may be the result of materials being flushed from the wetland under storm flows. This hypothesis is consistent with the relatively high BOD concentration observed during the storm flow sampling at Site 4. TKN, total phosphorus, and total suspended solid loads decrease at Site 3 suggesting that the lake is trapping particulate nutrients and sediment.

Site 8 exhibited the greatest total suspended solid load under storm flow conditions. This high load indicates a large amount of solids entering the Deep River/ Turkey Creek watershed from areas upstream of the 14 digit watershed. Urban land uses (high percent of impervious surface) dominate the land use in the area immediately upstream of Site 8. Agricultural land uses dominate the majority of the headwaters region of the larger Deep River/ Turkey Creek watershed. Both land uses have the potential to contribute large amounts of sediment to the river. In addition, the hardscape covering the urban area immediately upstream of Site 8 alters the landscape's natural hydrology. Rather than infiltrating the soil, rainwater that falls on impervious surface becomes surface runoff. Even if stormwater runoff is detained in detention basins, there is still a net increase in the volume of water reaching the creek. The impact of the increased water volume is evident in the bank erosion present at Site 8. This erosion contributes further to the total suspended solid load at Site 8.

To a large extent, flow governed nutrient and sediment loading of streams of the Deep River watershed (i.e., streams with higher flow rates also carried higher nutrient and sediment loads). **Table 5-6** summarizes sampling locations that loaded disproportionate amounts of the various parameters relative to discharge rate (i.e., these streams loaded more nutrients and/or sediment despite having smaller discharges than other streams where data was collected). Flow governed nitrate-nitrogen loads at all sites except Site 3 and Site 8, which carried more nitrate-nitrogen relative to discharge during storm flow sampling (Figure J). During base flow sampling Site 6 and Site 8 carried more ammonia-nitrogen despite lower flows (Figure K). Likewise, Site 4 carried a higher ammonia-nitrogen load relative to flow during the storm event. Site 1 carried a higher TKN load relative to other sites (Figure L). During the storm event, Site 4, Site 6, and Site 8 all carried disproportionately higher TKN and TP loads relative to flow rate (Figures L and M). These three sites, 4, 6, and 8, also carried larger amounts of suspended solids relative to rate of discharge (Figure N). Sediment loading rates varied from <9 to 1,206,928 kg/d (19.8 to 2,668,821 lb/d) depending on the flow regime and location.

Table 5-6: Watershed sites with disproportionate amount of pollutant loads relative to flow.

Site	Parameter	Event
Deep River Mouth (Site 1)	TKN	Base
Deep River Mouth (Site 1)	NH_3-N	Storm
Deep River at Lake George Dam (Site 3)	NO_3^--N	Storm
Lake George (Site 4)	TSS	Base
Lake George (Site 4)	NH_3-N	Storm
Lake George (Site 4)	TP	Storm
Lake George (Site 4)	TKN	Storm
Lake George (Site 4)	TSS	Storm
Deep River (Site 6)	NH_3-N	Base
Deep River (Site 6)	TKN	Storm
Deep River (Site 6)	TP	Storm
Deep River (Site 6)	TSS	Storm
Deep River County Park (Site 8)	NH_3-N	Base
Deep River County Park (Site 8)	NO_3^--N	Storm
Deep River County Park (Site 8)	TKN	Strom
Deep River County Park (Site 8)	TP	Storm
Deep River County Park (Site 8)	TSS	Storm